STUDY OF THE DELAWARE COUNTY NO. 3 INCINERATOR IN BROOMALL, PENNSYLVANIA

A Division of Technical Operations
Open-File Report (TO 3.1.010/0)

written by

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BACKGROUND

Incineration is an important method of solid waste processing in the United States, and although over 300 incinerators are in operation, little information on the performance of these units is available. It is, therefore, not surprising that the effects of incineration on the environment are little understood and frequently ignored.

An incinerator discharges effluents into the environment in three states: solid, liquid, and gaseous. The sources of these effluents are the processes of combustion, gas cleaning, and residue quenching. Any determination of the pollution contribution to the environment by incineration must be concerned with all these effluents.

The Bureau of Solid Waste Management, through the Division of Technical Operations, has initiated a program to characterize the performance of incinerators of different designs and configurations. The primary objectives of this program are to produce basic information that identifies the results of the incineration process and to develop reliable sampling methodology.

During the studies it is considered necessary to make a complete analysis of all features that affect the operation of the facility as well as those that influence its potential for environmental pollution. The operation of the facility is not altered in any way unless specific study objectives dictate a change. Therefore, no special effort is made to operate the facility at its design capacity; rather, it is tested at its "operating" capacity.

Reports from each study in this program will be prepared primarily for use by the management of the facility, although they will be available upon request to other interested technical personnel. Each report will contain only the data obtained during one individual study. Data comparisons with other studies will not be made in individual study reports. Summaries and comparisons of the data from all studies will be reported annually.

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SUMMARY

The Delaware County No. 3 incinerator is a traveling grate incinerator with two identical combustion units, each having a design capacity of 250 tons per 24 hr. There is a drying grate inclined at 25 degrees and a horizontal burning grate in each combustion chamber. The combustion products from each furnace pass through a wetted refractory baffle impingement collection system and are discharged into the atmosphere through a common stack. The residue drops from the grates into the quench tank where a drag conveyor removes the residue and discharges it into a truck for removal to a disposal site. Wastewater from the collection system and quench tank flows into a clarifier prior to its reuse or discharge into a watercourse.

Solid Waste

Of the total of 2,023 tons of solid waste processed during the study, an average of 76.7 percent was combustible and 23.3 percent was noncombustible on an "as received" basis. The average charging rate was 8.7 tons per furnace per hour which is 83.5 percent of design capacity. The principal portion of the combustibles was composed of paper products and food wastes. The major portion of the noncombustibles was composed of glass, ceramics and metals. The density of the waste ranged from 110 to 300 lb per cu yd and averaged 190 lb per cu yd. The solid waste had an average moisture content of 31.6 percent, a volatile content of

59.1 percent (dry basis), an ash content of 40.9 percent (dry basis), and a heat content of 3,659 Btu per lb as received. The solid waste contained on an average 21.0 percent carbon, 0.8 percent hydrogen, 19.1 percent oxygen, 0.2 percent sulfur, 0.3 percent chlorine, and 0.4 percent nitrogen.

Residue

Of the total of 785 tons of residue, an average of 8.2 percent was unburned combustibles, 45.5 percent was fines, 15.5 percent was metal, and 30.8 percent was glass and rocks. The density of the residue ranged from 1,420 to 1,500 lb per cu yd and averaged 1,455 lb per cu yd. The residue had an average moisture content of 27.3 percent, a volatile content of 5.2 percent (dry basis), an ash content of 94.8 percent (dry basis), and a heat content of 488 Btu per lb (dry basis). The residue contained on an average 3.4 percent carbon, 0.6 percent hydrogen, 0.8 percent oxygen, 0.2 percent sulfur, 0.0 percent chlorine, and 0.1 percent nitrogen.

Fly Ash

The fly ash contained an average of 34.9 percent moisture and on a dry basis contained 3.6 percent volatiles and 96.4 percent ash with a heat content of 367 Btu per lb. The fly ash contained 1.3 percent carbon, 0.2 percent hydrogen, 0.0 percent oxygen, 0.6 percent sulfur, 0.0 percent chlorine, and 0.1 percent nitrogen.

Process and Wastewater

The average total solids content of the process water, scrubber effluent water, clarifier effluent water, and quench water was 399; 4,663; 4,201; and 2,965 mg per liter, respectively. The average suspended and dissolved solids were 27 and 372; 250 and 4,413; 139 and 4,062; and 430 and 2,535 mg per liter, respectively.

The pH of the process water varied from 6.5 to 7.1, and the temperature averaged 54 F. The alkalinity was 205 mg per liter, the chloride content was 80 mg per liter, and the phosphate content was 81 mg per liter.

The scrubber effluent water was acidic (pH varied from 3.8 to 4.3), with an average temperature of 127 F. The chloride, sulfate, and phosphate contents were 1,852; 1,830; and 90 mg per liter, respectively. The hardness was 514 mg per liter.

The clarifier effluent water was acidic (pH varied from 4.6 to 5.1) with an average temperature of 123 F. The chloride, sulfate, and phosphate contents were 1,706; 1,685; and 67 mg per liter, respectively. The alkalinity was 14 mg per liter, and the hardness was 484 mg per liter.

The quench water was basic (pH varied from 9.0 to 10.1), and the average temperature was 128 F. The alkalinity was 338 mg per liter, and the hardness was 220 mg per liter. The chloride, sulfate, and phosphate contents were 847, 880, and 58 mg per liter, respectively.

Stack Effluents

The average dust loadings were 0.36 gr per scf corrected to 12 percent carbon dioxide, 0.71 lb per 1,000 lb of dry flue gas corrected to 50 percent excess air, 148 lb per hr, and 7.38 lb per ton of waste charged. The average flow rate was 274,700 actual cfm (acfm) and 146,000 standard cfm (scfm) with 4.1 percent carbon dioxide and 374 percent excess air.

Plant Efficiency

The plant achieved a volatile reduction of 96.3 percent, a heat release of 96.1 percent, and a volume reduction of 94.8 percent.

Bacteriological Analyses

The incinerator reduced the total viable bacterial cell count from an average of 1.2×10^7 counts per gram in the solid waste to 1.7×10^4 counts per gram in the residue and 7.3×10^5 counts per gram in the fly ash. The heat resistant spores were reduced from an average of 5.7×10^3 counts per gram in the solid waste to 1.7×10^2 counts per gram in the residue and 4.0×10^3 counts per gram in the fly ash. The solid waste contained an average of 6.7×10^6 counts per gram of total coliforms and 5.9×10^6 counts per gram of fecal coliforms. No coliforms were detected in the residue while the fly ash contained an average of 7.5×10^4 counts per gram of total coliforms and 7.5×10^4 counts per gram of fecal coliforms.

The process water, which comes from the sewage treatment plant, contained a high density of bacteria; the average viable bacterial cell count was 7.0×10^8 counts per 100 ml. The clarifier effluent and quench waters had lower densities after their respective uses: 4.5×10^6 counts per 100 ml for the clarifier effluent and 5.1×10^4 counts per 100 ml for the quench water.

Salmonella was not isolated at any source.

Cost Analyses

The annual cost for the year, January 1969 to January 1970, was $5.73 per ton of solid waste processed. The capital investment cost was $4,566 per ton of design capacity.

The total operating cost of $366,312 waw 64.6 percent of the total annual cost, while the total financing and ownership costs of $200,443 was 35.4 percent of the total annual cost. When the operating cost is based on cost centers, 27.9 percent was spent on receiving, 43.6 percent was spent on volume reduction, and 28.5 percent was spent in effluent treatment.

Industrial Hygiene

The industrial hygiene survey found that during the study period the dust concentration and noise levels were below maximum permissible levels and presented no health hazard. The potential heat stress presented no health hazard at the time of the study period, but when the outdoor temperature does exceed 75 F, the heat stress may be excessive in the middle of the furnace floor between the furnaces.

In two plant areas, the furnace feed platform (at the top of the drying grate) and the quench tank area, the lighting levels were below recommended levels.

Excessive smoke is generated in a 5-in. gap between the charging hopper and the drying grate. This smoke is probably the most serious hazard in the plant.

INTRODUCTION

In September, 1969, Mr. A. B. Favor, Executive Administrator, Delaware County Disposal Department, was contacted about the possibility of having the Bureau of Solid Waste Management test the Delaware County No. 3 Incinerator. The purpose of the test was to develop basic information pertaining to the operation of the incinerator and its potential impact on the surrounding environment. Mr. Favor agreed to the testing, and the study was conducted during the week of January 26 to 30, 1970.

FACILITY DESCRIPTION AND OPERATION

General

The Delaware County No. 3 Incinerator is located in Marple Township, Broomall, Pennsylvania. The plant was placed in operation in late summer of 1962. The Delaware County No. 3 Incinerator is one of three incinerators serving the 600,000 people of Delaware County, Pennsylvania. The incinerator operation is under the administrative control of Mr. A. B. Favor, Executive Administrator, Delaware County Disposal Department. Mr. R. L. Cummings, plant superintendent, is directly in charge of its daily operation. The operating funds are derived from the county budget.

The incinerator is located in a small industrial park at Marpit Drive and Sussex Boulevard. The plant is oriented in a north-south direction with the solid waste storage pit located on the north side of the plant and the stack located on the south side of the plant. Figure 1 shows the general layout.

The design capacity of the incinerator is 500 tons per 24 hr of operation based on solid waste having a heat content of 5000 Btu per lb. The plant has two identical but independent furnaces. They are fed by two P. and H.* 4-ton overhead cranes from a storage pit that can hold 400 tons of solid waste. The

*Mention of specific products or equipment does not imply endorsement by the U. S. Public Health Service.

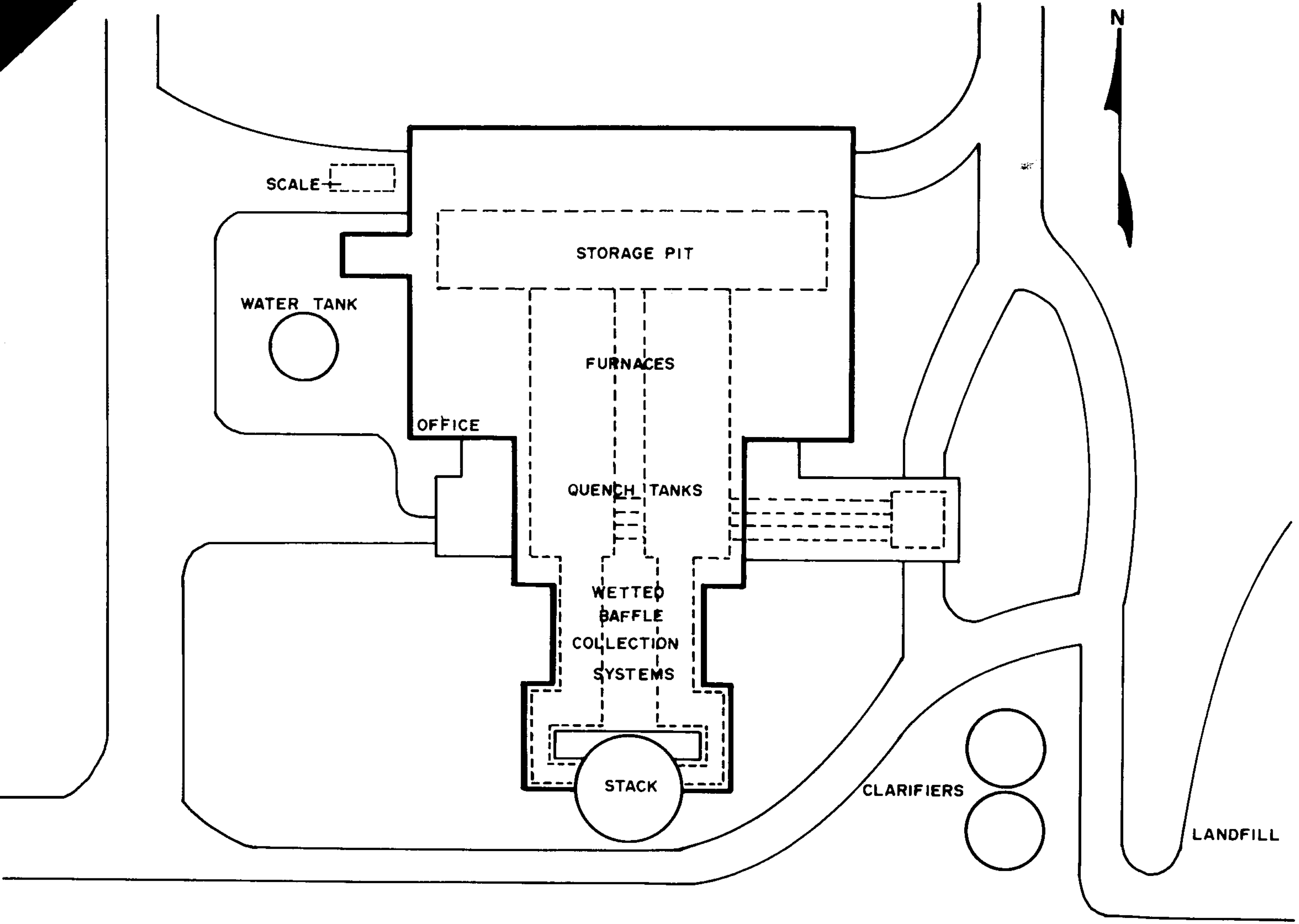

Figure I. General plant layout.

storage pit's dimensions are 84 ft long, 25 ft wide and 25 ft deep. The tipping area, storage pit and furnaces are enclosed in a concrete and brick building. A scale at the entrance of the tipping area weighs all incoming solid waste accepted from municipal, commercial, and industrial sources. The furnaces have a common stack and two residue conveyors. The residue conveyors discharge into a hopper for loading of the residue truck.

Furnaces

The two furnaces (see Figure 2) were built by Morse Boulger, Inc. and are of the traveling grate type. Each furnace has a solid waste charging hopper and chute. The waste falls by gravity down the charging chute onto a drying grate inclined at 25 degrees. The drying grate is 17 ft long and 8 ft wide. The refuse falls from the drying grate to a horizontal burning grate that is 31 ft long and 8 ft wide. Both the inclined and horizontal traveling grates are manufactured by Combustion Engineering, Inc. Two Reeves variable speed drive mechanisms permit regulation of the speed of both the inclined and horizontal traveling grates.

Combustion air is provided to each furnace by separate forced draft fan systems. Underfire air is manually regulated by a system of dampers to each zone of the inclined and horizontal grates, while overfire air is introduced at two points in the furnace roof. The overfire air is introcuced through six nozzles at each point of admission.

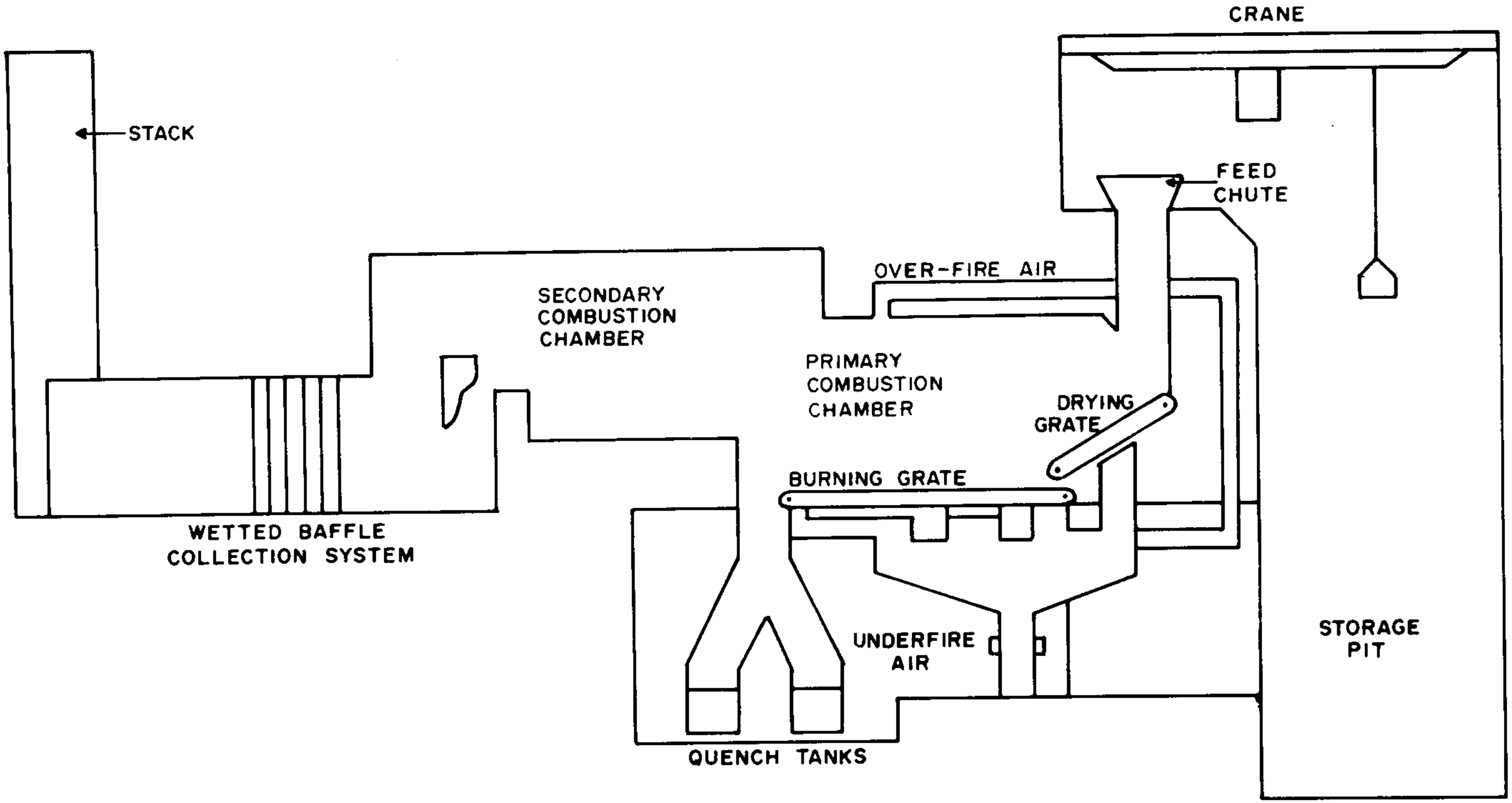

Figure 2. Furnace cross section.

Residue Removal System

The residue from the furnace falls off the end of the horizontal traveling grate into a vertical chute. A flap-gate arrangement permits selection of one of two discharge chutes in an inverted Y-duct arrangement. The legs of the inverted Y-duct discharge into separate quench tanks. A continuous-flighted drag conveyor system elevates the residue into a dumping hopper. When full, the operator discharges the residue into a truck for disposal at a nearby landfill.

Air Pollution Control Equipment

The combustion gases leave the top rear of the furnace chamber and enter a secondary combustion chamber. From this combustion chamber, the gases pass over a bridgewall and are split by a suspended baffle. Having passed either over or under the baffle, the gases pass into a long settling chamber with a wetted refractory baffle impingement collection system. The floor of the long chamber is pitched. Settled ash is flushed from the floor by water sprays.

The baffle system (Figure 3) consists of three rows of refractory brick, v-shaped columns, installed across the entrance of the 12-ft wide settling chamber. The chamber is 20 ft high at this point. In the first row there are five columns with an 18-in. outside dimension on each leg. Therefore, there is a 6 1/2-in. free space opening between each column across the first row of columns. The next two rows of columns are staggered, in relation to adja-

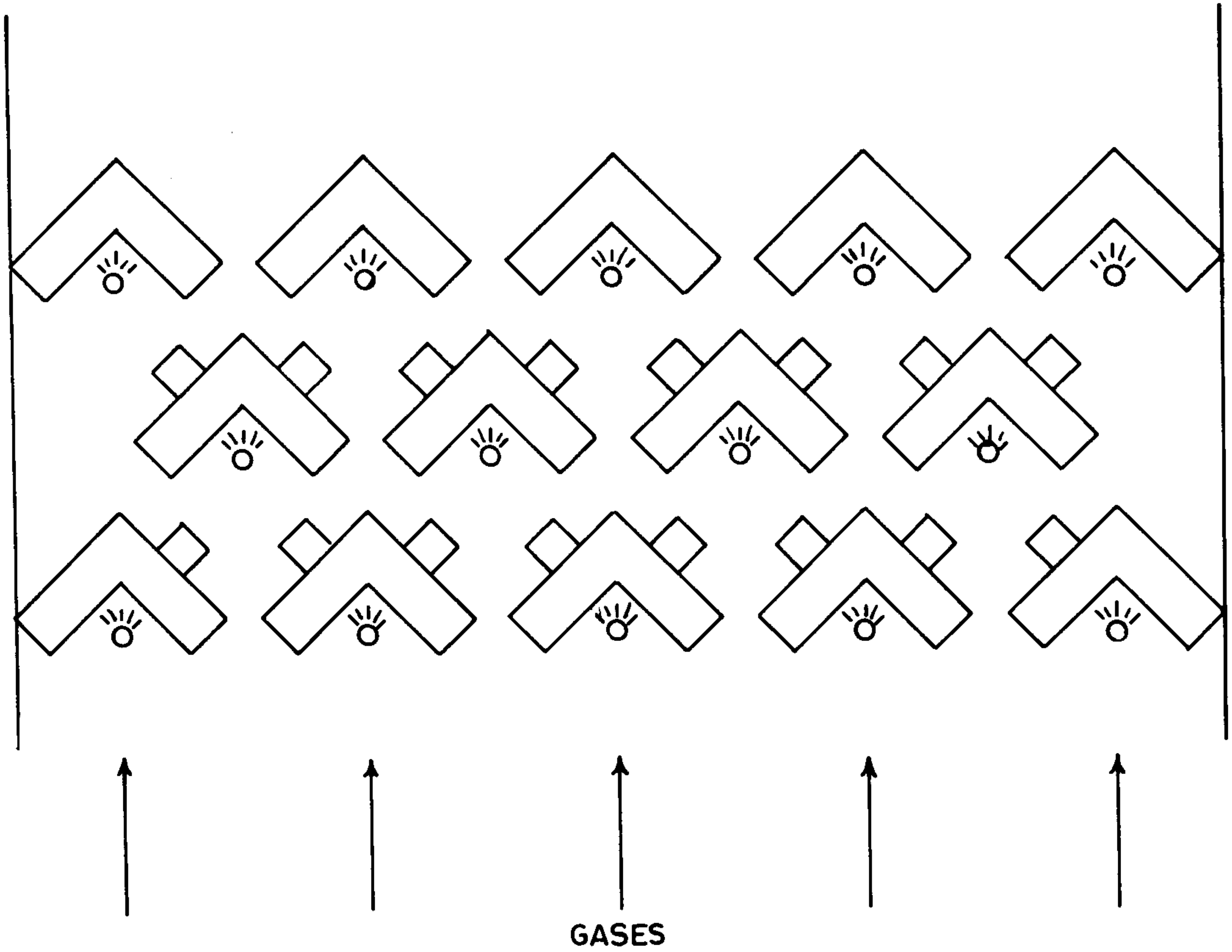

Figure 3. Top view of refractory baffle impingement collection system.

cent rows, to allow only a 4 1/2-in. free space opening between rows. Row two has four columns and row three has five. Sprays at the top of each column keep water continuously flowing down the face of the columns.

The cleaned combustion gases leave the dust collector and enter a dry bottom flue. The flue from each furnace discharges into the base of the stack on opposite sides. The stack is double walled, refractory lined, with a height of 250 ft and an inside diameter of 11 ft at the top and 18 ft at the bottom.

Fly Ash and Wastewater Handling

A pitched sump along the outside wall of each collection chamber carries the collected fly ash to two large Dorr clarifiers. These clarifiers separate the collected fly ash from the water slurry. The fly ash is continuously removed from the clarifiers and dumped onto a concrete slab; the fly ash is removed periodically to the landfill by a front-end loader.

The quench water from the residue quench tank is bled into the clarifiers to neutralize the scrubber water before the scrubber water is recirculated.

Instrumentation

An upright instrument panel is located in front of each furnace on the furnace floor. This instrument panel contains gauges for displaying the temperatures and drafts of the furnace. The following temperatures and drafts are measured: furnace temperature and draft, stack temperature and draft, and drafts for the forced draft fan outlet, the overfire air duct and four zones under the drying and burning grates. Grate speeds are recorded on the panel or read directly from the control on the side of each furnace.

Recorders for furnace temperature, smoke density and grate speeds are located in the superintendent's office.

Operation

The incinerator normally operates 24 hr a day from early Monday morning to late Saturday morning. Fire-up is started as soon as there is sufficient solid waste for normal operation on Monday morning, and furnace shut-down is completed on Saturday afternoon to allow for general maintenance.

All incoming solid waste is weighed, and the weight recorded. The residue is not weighed as it leaves the incinerator for landfilling. Also, the accumulated fly ash is not weighed before it leaves the incinerator for landfilling.

The work day is divided into three, 8-hr shifts. There are seven regular jobs: plant superintendent, foreman, craneman, ash truck driver, stoker, conveyor attendant, and general laborers. The superintendent and the foreman direct the incinerator's rate of burning by either adjusting the speeds on the inclined and horizontal grates or by adjusting the underfire air flow or the underfire-overfire air distribution ratio.

For the most part, the operation was normal for the study period. However, some burning was curtailed during the late shifts to conserve solid waste for the next day's burning. The charging rate was normal during all the stack tests because of the above precautions.

STUDY PROCEDURES

This section discusses the methods used to collect and analyze the following samples: (1) solid waste, (2) residue, (3) stack particulate emissions, (4) stack gases, and (5) process water. The sampling for the bacteriological and industrial hygiene surveys is also described. The sampling locations (Figure 4) of solid, liquid, and gaseous products from the incinerator were based upon their flow systems and ease of sampling. Samples were collected according to the schedule shown in Table 1.

During the field study, the incoming solid waste and outgoing residue and fly ash were weighed. These weights, along with other pertinent operational data, were recorded in the "Daily Report" compiled at the incinerator. Copies of the "Daily Report" are included in Appendix D.

Solid Waste

The amount of solid waste burned during the study and the charging rate were determined from the "Daily Report" compiled for each day during the study.

A total of eight samples, visually representative of the waste being burned, were obtained from the storage pit. The bulk density of the solid waste was obtained by filling four 20-gal containers and obtaining their net weight. No effort was made to compact the wastes during placement in the container.

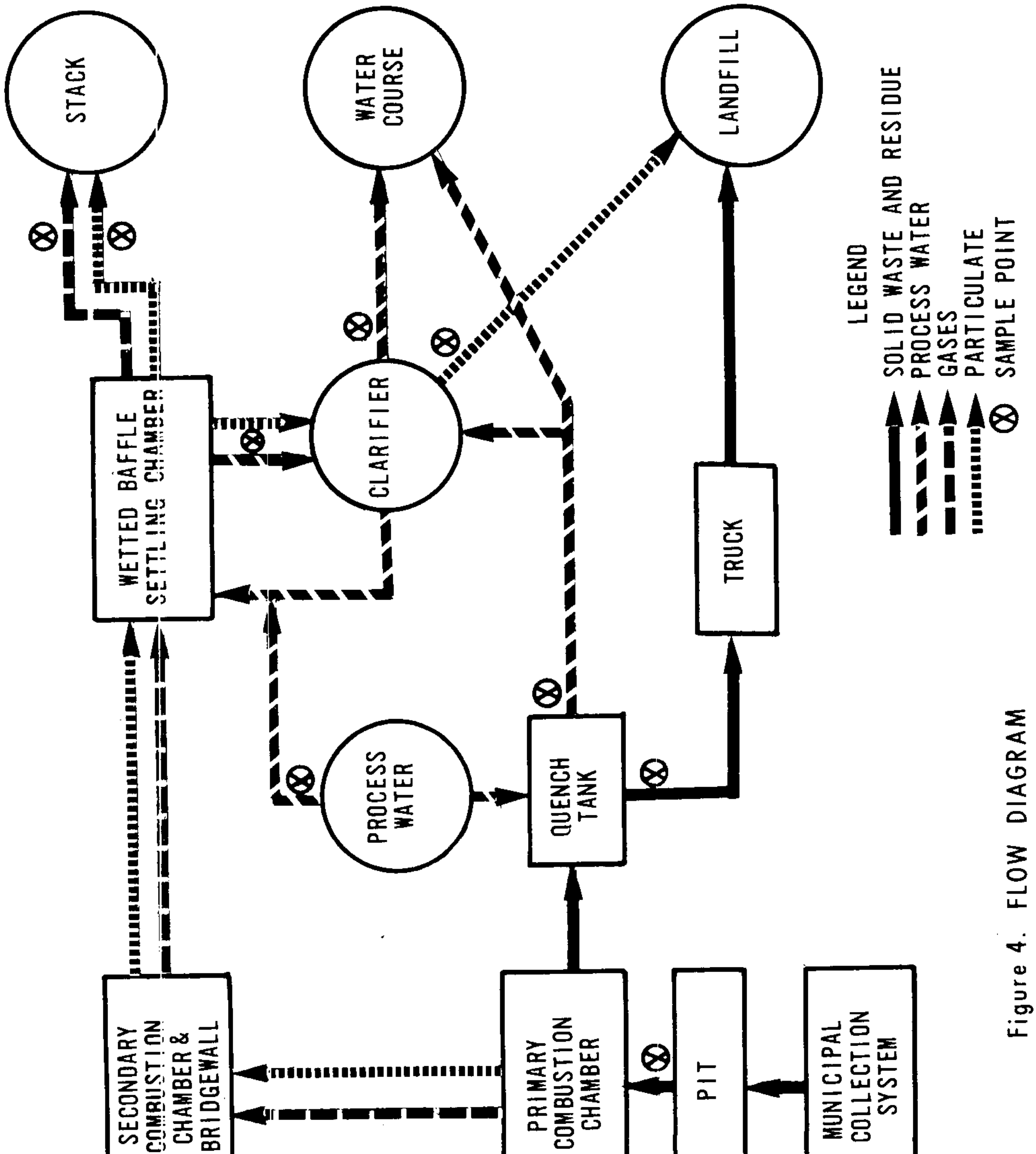

Figure 4. FLOW DIAGRAM

TABLE I

SAMPLING SCHEDULE

Source	Samples				
	Monday (1-26-70)	Tuesday (1-27-70)	Wednesday (1-28-70)	Thursday (1-29-70)	Friday (1-30-70)
Stack particulates	-	1	2,3	4	-
Solid waste	1*	2*,3	4,5*	6*,7	8*
Residue†	1	2	3	4	5
Process water	1	2	3	4	5
Stack gases	Grab	Grab and composite	Grab and composite	Grab and composite	
Fly ash†	1	2	3	4	5

*Samples returned to laboratory for analyses

†All samples returned to laboratory for analyses

These samples were then spread on a drop cloth and hand-sorted into nine categories:

Combustibles	Noncombustibles
Food waste	Metal products
Paper products	Glass and ceramics
Plastic, rubber and leather	Ash, rocks, and dirt
Wood	
Garden waste	
Textiles	

Each category was weighed and the percent by weight on an "as received" basis for each category was determined. Using these percentages, 10- to 15-lb laboratory samples were reconstituted from five of the composition samples keeping the combustible and noncombustible portions separate. To prevent moisture loss, each of these samples was placed in two plastic bags, one inside the other, and each bag was knotted separately.

At the laboratory, the reconstituted samples were dried at 100 C to constant weight to determine the moisture content. The combustible portions were then processed in a hammermill to reduce the maximum particle size to 1 in. The ground product was spread on a plastic sheet and thoroughly mixed. The sample was then successively mixed and quartered discarding alternate quarters. This process was repeated until a sample weight of 3 to 4 lb was obtained.

A 100-gram portion of the ground sample was redried. The sample was then further ground in a Wiley mill until it would pass through a 2-mm mesh sieve. The volatile* and ash fractions[1] and the heat content[2] were then determined. Ultimate analyses[3] for carbon, hydrogen, oxygen, nitrogen, sulfur, and chlorine were performed on the ground sample. The ash content of the sample submitted for ultimate analyses was also determined.

Residue

The amount of residue landfilled during the study was determined from the "Daily Report" compiled for each day during the study.

Samples weighing from 30 to 40 lb were collected from the residue conveyor. The bulk density of the residue was obtained by filling a 6-gal container and obtaining the net weight. No effort was made to compact the residue during placement in the container.

The samples were then dumped on a large canvas sheet and manually separated into four categories: metals; glass, ceramics, rocks, bricks, etc.; unburned combustibles†; and fines (unidentifiable material passing a ½-in. wire mesh screen). After separation, each category was weighed and the percent by weight on a wet basis was determined. Each category was individually sealed in plastic bags to preserve the moisture content and returned to the laboratory for further analyses.

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*Material determined by a laboratory analysis

†Material that can be visually identified as being from one of six categories of combustible materials used to define the composition of incoming waste, such as charred paper, wood, orange peels, etc.

At the laboratory, all portions were dried and the fines and unburned combustibles were processed in the same fashion as the solid waste samples, with the following exceptions: all laboratory samples and the 100-gram portion of same were dried at 100 to 105 C to constant weight to determine the moisture content, the fines were further ground to 60 mesh on an Iler pulverizer, and benzoic acid was used as a combustion aid in the calorimeter to determine the heat content. Ultimate analyses were also performed on the ground samples.

Fly Ash

The amount of fly ash collected by the clarifiers during the study was weighed. All the fly ash collected during the furnace clean-out was also weighed. These weights were recorded on the last "Daily Report" compiled during the study.

A 1-liter grab sample from the fly ash collected by the clarifier was taken each morning during the study.

At the laboratory, the density was determined, as well as all the analyses performed on the solid waste. Ultimate analyses were also performed on one sample.

Process and Wastewater

Each source of water was sampled to determine its physical and chemical characteristics. These sources were the process water, scrubber effluent water, clarifier effluent water, and quench water.

A 1-liter grab sample from each source was taken each morning during the study. These samples were shipped to the laboratory to be analyzed for solids[4], chloride[4], hardness[4], sulfate[4], and phosphate[4,5]. The pH[6], temperature, and alkalinity[4] of each sample were determined in the field.

Stack Effluents

Particulate Emissions. On Monday, January 26, 1970, the equipment was assembled and preliminary measurements were made to determine the moisture content, carbon dioxide content, and velocity of the stack gases. One particulate test was conducted on Tuesday, two on Wednesday, and one on Thursday. The sampling train and the sampling and analytical procedures used are described in "Specifications for Incinerator Testing at Federal Facilities"[7].

The sampling ports were located 48 ft above the stack foundation and approximately 90° apart. Samples were taken from the sampling ports, using a 24-point traverse sampling on the two perpendicular diameters in a 179-in. round stack. The sampling ports were located three diameters from the top of the stack inlet and 15 diameters from the stack exit. The velocity head ranged from 0.07 to 0.21 in. of water. Samples were taken using a 0.373-in. nozzle. An actual sampling time of 3 min was used at each point.

During the test, whenever excessive accumulations of particulate on the filters hindered isokinetic sampling, the filters were replaced and the test continued to completion.

Stack Gases. During the particulate test, a composite sample of the stack gases was taken. The composite sample was collected in a Tedlar bag by slowly filling the bag with stack gases throughout the test period. This sample was used to determine the dry gas composition by using an Orsat Apparatus[8].

Grab samples for NO_x and HCl were taken on Tuesday, Wednesday, and Thursday. The sampling train used is described in "Determination of Nitrogen Oxides in Stack Gas: Phenoldisulfonic Acid Method"[9]. The Phenoldisulfonic Acid Method[9] was used for the NO_x analysis while the Mercuric Nitrate Method[4] was used for the HCl analysis.

Cost Analyses

The cost data were obtained by checking all cost records kept by the plant and any administrative group keeping pertinent records. In addition, the personnel who maintained the cost records were questioned to verify and adjust correctly the cost data to fit the Bureau's cost-accounting scheme.

Bacteriological Analyses

Samples for the bacteriological analyses were collected from the following sources: solid waste, residue, fly ash, process water, quench water effluent, and clarifier water effluent. These samples were analyzed for total viable cell count, heat resistant spore count, total coliforms, fecal coliforms, and salmonella.[10]

Industrial Hygiene

During the study period, a survey of the plant was performed by an industrial hygienist to identify those areas in the plant where workers were steadily employed and other areas of possible high exposure to environmental hazards. At these designated areas, tests were performed on noise level, dust, heat stress and effective heat, lighting and smoke.

RESULTS AND DISCUSSION

This section presents the data obtained from the analyses of samples taken during the field study of the Delaware County No. 3 Incinerator.

Solid Waste Processed

The amount of solid waste processed during the study was 2,023 tons (Table 2). The amounts of residue and fly ash collected was 785 and 6 tons, respectively. The furnaces operated 232 hr for an average of 8.7 tons per furnace hr.

Solid Waste Characteristics

The physical composition data (Table 3) was calculated on an "as received" basis. The densities were calculated on a wet basis as sampled from the storage pit. The values for samples No. 1 through 8 are 110, 300, 165, 140, 190, 195, 190, and 225 lb per cu yd, respectively. The average density was 190 lb per cu yd.

The moisture content of the solid waste was obtained from the analysis of the whole sample, while the volatile, ash, and heat content were obtained from the analyses of the combustible portion. The results (Table 4) were calculated for the complete sample on the assumption that the noncombustibles contained no heat or volatile material. The ash and volatile fractions were calculated on a dry basis. The heat and moisture contents were calculated on an "as received" basis. Example calculations are presented in Appendix A.

TABLE 2

SOLID WASTE PROCESSED

Date	Solid waste received[+]				Residue dumped[+]		Fly ash* dumped (tons)	Total fur-nace hours	Tons burned per furnace hour
	Truck loads	Tons re-ceived	Bucket loads charged	Tons burned	Truck loads	Tons dumped			
1-26-70	130	452	348	318	20	109	-	30	10.6
1-27-70	124	410	525	482	36	193	-	48	10.0
1-28-70	67	205	402	337	23	115	-	48	7.0
1-29-70	121	395	384	359	24	128	-	48	7.5
1-30-70	126	407	494	431	35	176	-	48	9.0
1-31-70	-	-	123	96	11	64	6	10	9.6
Totals	568	1,869	2,276	2,023	149	785	6	232	-
Average	-	-	-	-	-	-	-	-	8.7

*Fly ash from the clarifiers and the weekend furnace clean-out, with each source contributing equal amounts

[+]All weights are "wet weight".

TABLE 3

SOLID WASTE COMPOSITION

Component	Sample																Average percent
	1		2		3		4		5		6		7		8		
	1-26-70 pm*		1-27-70 am*		1-27-70 pm		1-28-70 am		1-28-70 pm*		1-29-70 am*		1-29-70 pm		1-30-70 am*		
	lb	%	lb	%	lb	%	lb	%	lb	%	lb	%	lb	%	lb	%	
Combustibles:																	
Food waste	39.0	16.0	49.5	10.5	71.3	26.8	51.5	18.5	69.3	17.4	73.8	19.9	41.3	14.6	38.3	17.0	17.6
Garden waste	2.0	0.8	0.3	0.1	2.5	0.9	0.5	0.2	0.8	0.2	0.3	0.1	0.5	0.2	1.3	0.6	0.4
Paper products	121.3	49.8	318.3	67.5	108.3	40.7	136.0	48.9	180.3	45.4	174.3	47.1	176.3	62.3	113.3	50.4	51.5
Plastic, rubber, leather	5.5	2.3	14.3	3.0	8.3	3.1	18.0	6.5	16.5	4.2	9.8	2.6	9.3	3.3	11.0	4.9	3.7
Textiles	8.0	3.3	9.3	2.0	5.0	1.9	7.0	2.5	11.3	2.8	6.3	1.7	5.0	1.8	1.3	0.6	2.1
Wood	3.3	1.3	1.3	0.3	6.8	2.5	1.5	0.5	9.3	2.3	8.5	2.3	2.5	0.9	1.8	0.8	1.4
Total	179.1	73.5	393.0	83.4	202.2	75.9	214.5	77.1	287.5	72.3	273.0	73.7	234.9	83.1	167.0	74.3	76.7
Noncombustibles:																	
Metals	24.3	10.0	29.8	6.3	22.8	8.6	16.0	5.8	33.3	8.4	38.8	10.5	17.5	6.2	24.0	10.7	8.3
Glass and ceramics	32.5	13.4	35.5	7.5	40.0	15.0	40.0	14.4	60.0	15.1	39.0	10.6	27.5	9.7	21.5	9.6	11.9
Ash, rocks, dirt	7.5	3.1	13.3	2.8	1.3	0.5	7.5	2.7	16.8	4.2	19.3	5.2	2.8	1.0	12.3	5.4	3.1
Total	64.3	26.5	78.6	16.6	64.1	24.1	63.5	22.9	110.1	27.7	97.1	26.3	47.8	16.9	57.8	25.7	23.3
Grand total	243.4	100.0	471.6	100.0	266.3	100.0	278.0	100.0	397.6	100.0	370.1	100.0	282.7	100.0	224.8	100.0	100.0

*A proportionate amount returned to laboratory for analyses

TABLE 4

PROXIMATE ANALYSIS OF SOLID WASTE*

Date collected	Sample number	Characteristic			
		As sampled		Dry basis	
		Moisture (%)	Heat (Btu/lb)	Volatiles (%)	Ash (%)
1-26-70	1	25.3	4,184	62.5	37.5
1-27-70	2	48.1	2,870	61.3	38.7
1-28-70	5	32.0	3,225	53.7	46.3
1-29-70	6	25.8	3,987	59.5	40.5
1-30-70	8	27.0	4,031	58.5	41.5
Average		31.6	3,659	59.1	40.9

*See Appendix A.

The data from the ultimate analyses of the solid waste (Table 5) were adjusted to an "as received" basis by assuming that each sample contained only eight constituents. The results were accordingly adjusted on a weight basis to 100 percent.

Residue

The data from the residue separation (Table 6) are on an "as sampled" basis.

The densities of the residue samples were calculated on a wet basis as sampled from the conveyor. The values for samples No. 1 through 4 are 1,420; 1,465; 1,430; and 1,500 lb per cu yd, respectively. The average density was 1,455 lb per cu yd.

The moisture content of the residue was obtained from the analysis of the whole sample, while the volatile, ash, and heat content were obtained from the analyses of the fines and unburned combustible portions only. The results (Table 7) were calculated for the complete sample with the assumption that the glass and metal contained no heat or volatile material. The moisture content is only representative of the sampling location, which was the residue conveyor. The ash and volatile fractions and the heat content were calculated on a dry basis. Example calculations are presented in Appendix B.

The data from the ultimate analyses of the residue (Table 8) were adjusted to an "as sampled" basis by assuring that each sample contained only eight constituents, and the results were accordingly adjusted on a weight basis to 100 percent.

TABLE 5

ULTIMATE ANALYSES OF SOLID WASTE

(PERCENT)*

Date collected	Sample number	Carbon	Hydrogen	Oxygen	Sulfur	Chlorine	Nitrogen
1-26-70	1	23.0	0.9	22.0	0.2	0.3	0.5
1-28-70	5	18.2	0.8	16.7	0.1	0.3	0.4
1-30-70	8	21.8	0.6	18.6	0.2	0.4	0.4
Average		21.0	0.8	19.1	0.2	0.3	0.4

*Inert and moisture percentages omitted

TABLE 6

RESIDUE COMPOSITION

Component	Sample number										Average percent by weight
	1 1-26-70		2 1-27-70		3 1-28-70		4 1-29-70		5 1-30-70		
	Weight (lb)	Percent by weight	Weight (lb)	Percent by weight	Weight (lb)	Percent by weight	Weight (lb)	Percent by weight	Weight (lb)	Percent by weight	
Metals	4.0	9.6	6.5	15.2	5.8	14.1	7.5	17.6	5.0	20.8	15.5
Rocks, bricks, ceramics, and glass	8.8	20.9	15.3	35.7	9.8	23.9	14.5	34.1	9.5	39.6	30.8
Fines	23.8	56.9	17.5	40.9	22.8	55.9	19.8	46.5	6.5	27.1	45.5
Unburned combustibles	5.3	12.6	3.5	8.2	2.5	6.1	0.8	1.8	3.0	12.5	8.2
Total	41.9	100.0	42.8	100.0	40.9	100.0	42.6	100.0	24.0	100.0	100.0

TABLE 7

PROXIMATE ANALYSIS OF RESIDUE

Date collected	Sample number	Characteristic			
		As sampled	Dry basis		
		Moisture (%)	Heat (Btu/lb)	Volatiles (%)	Ash (%)
1-26-70	1	30.8	938	10.0	90.0
1-27-70	2	20.4	480	4.8	95.2
1-28-70	3	31.8	450	5.2	94.8
1-29-70	4	25.6	203	2.4	97.6
1-30-70	5	27.7	368	3.8	96.2
Average		27.3	488	5.2	94.8

See Appendix B.

TABLE 8

ULTIMATE ANALYSIS OF RESIDUE AND FLY ASH

(PERCENT)*

Date collected	Sample number	Carbon	Hydrogen	Oxygen	Sulfur	Chlorine	Nitrogen
Residue:							
1-26-70	1	4.6	1.1	0.4	0.2	0.1	0.2
1-27-70	2	2.7	0.4	0.9	0.1	0.0	0.1
1-28-70	3	3.0	0.2	1.2	0.2	0.0	0.1
Average		3.4	0.6	0.8	0.2	0.0	00.1
Fly ash†							
1-30-70	5	1.3	0.2	0.0	0.6	0.0	0.1

*Inert and moisture percentages omitted

†Dry basis

Fly Ash

The moisture, volatile, ash, and heat content of the fly ash were obtained from the analysis of the whole sample. The results (Table 9) present the moisture content and the volatile, ash, and heat contents on a dry basis.

The data from the ultimate analyses of the fly ash (Table 8) were adjusted to a dry basis by assuming that each sample contained only seven constituents, and the results were accordingly adjusted on a weight basis to 100 percent.

The densities of the fly ash samples were calculated on a dry basis. The values for samples No. 1 through 6 and the furnace clean-out sample are 1,410; 1,415, 1,440; 1,395; 1,655; 1,430; and 1,295 lb per cu yd, respectively. The average density of samples No. 1 through 6 was 1,460 lb per cu yd.

Process and Wastewater

The results of the analyses for solids in the process water, scrubber effluent water, clarifier effluent water, and quench water are presented in Table 10.

The results of the analyses for the chemical characteristics of the process water, scrubber effluent water, clarifier effluent water, and quench are presented in Table 11.

Stack Effluents

The data from the Orsat analyses (Table 12) of the samples obtained from the stack were used to adjust the particulate emissions to 12 percent carbon dioxide. The results of the

TABLE 9

PROXIMATE ANALYSIS OF THE FLY ASH

Sample number	Date collected	As sampled	Dry basis		
		Moisture (%)	Heat (Btu/lb)	Volatiles (%)	Ash (%)
1	1-26-70	25.7	35	1.8	98.2
2	1-27-70	48.4	580	5.0	95.0
3	1-28-70	38.0	483	4.5	95.5
4	1-29-70	34.6	366	3.8	96.2
5	1-30-70	25.0	195	1.8	98.2
6	1-31-70	37.8	542	4.6	95.4
Average		34.9	367	3.6	96.4
Fly ash from furnace clean-out on 1-31-70		48.2	188	2.8	97.2

TABLE 10

WASTEWATER SOLIDS CONCENTRATION

Sample	Total solids					Suspended solids					Dissolved solids (mg/liter)
	Total (mg/liter)	Volatiles		Ash		Total (mg/liter)	Volatiles		Ash		
		mg/liter	%	mg/liter	%		mg/liter	%	mg/liter	%	
No.1											
Process water	366	140	38.3	226	61.7	37	25	67.6	12	32.4	329
Scrubber effluent water	3,950	1,030	26.1	2,920	73.9	376	84	22.3	292	77.7	3,574
Clarifier effluent water	3,528	858	24.3	2,670	75.7	75	23	30.7	52	69.3	3,453
Quench water	2,331	648	27.8	1,683	72.2	439	180	41.0	259	59.0	1,892
No. 2											
Process water	419	130	31.0	289	69.0	42	30	71.4	12	28.6	377
Scrubber effluent water	4,123	1,109	26.9	3,014	73.1	258	59	22.9	199	77.1	3,865
Clarifier effluent water	3,432	932	27.2	2,500	72.8	72	24	33.3	48	66.7	3,360
Quench water	3,859	980	25.4	2,879	74.6	699	236	33.8	463	66.2	3,160
No. 3											
Process water	396	104	26.3	292	73.7	13	13	100.0	0	0.0	383
Scrubber effluent water	4,378	1,228	28.0	3,150	72.0	173	69	39.9	104	60.1	4,205
Clarifier effluent water	3,828	1,091	28.5	2,737	71.5	99	42	42.4	57	57.6	3,729
Quench water	3,420	756	22.1	2,664	77.9	559	175	29.2	424	70.8	2,861
No. 4											
Process water	403	94	23.3	309	76.7	15	15	100.0	0	0.0	388
Scrubber effluent water	4,661	1,367	29.3	3,294	70.7	230	78	33.9	152	66.1	4,431
Clarifier effluent water	4,565	1,310	28.7	3,255	71.3	255	86	33.7	169	66.3	4,310
Quench water	2,143	456	21.3	1,687	78.7	233	54	23.2	179	76.8	1,910
No. 5											
Process water	411	162	39.4	249	60.6	28	28	100.0	0	0.0	383
Scrubber effluent water	6,202	2,185	35.2	4,017	64.8	211	101	47.9	110	52.1	5,991
Clarifier effluent water	5,654	1,930	34.1	3,724	65.9	194	108	55.7	86	44.3	5,460
Quench water	3,074	946	30.8	2,128	69.2	219	131	59.8	88	40.2	2,855

TABLE 11

WASTEWATER CHEMICAL CHARACTERISTICS

Sample	pH	Temperature (F)	Alkalinity (mg $CaCO_3$/liter)	Chloride (mg/liter)	Hardness (mg $CaCO_3$/liter)	Sulfate (mg SO_4/liter)	Phosphate (mg PO_4/liter)
No. 1							
Process water	6.5	52	204	64	52	175	69
Scrubber effluent water	4.3	127	-	1,399	551	1,415	84
Clarifier effluent water	4.9	118	6	1,347	549	1,368	78
Quench water	9.6	135	340	512	36	400	112
No. 2							
Process water	7.1	59	196	84	54	173	71
Scrubber effluent water	4.3	133	-	1,606	435	1,550	100
Clarifier effluent water	5.1	140	26	1,386	382	1,370	50
Quench water	10.1	144	372	1,045	217	1,200	64
No. 3							
Process water	7.0	52	204	75	60	168	82
Scrubber effluent water	3.8	129	-	1,816	484	1,825	92
Clarifier effluent water	4.9	120	20	1,621	442	1,563	56
Quench water	9.4	117	264	1,169	338	1,188	52
No. 4							
Process water	7.1	52	216	87	53	153	104
Scrubber effluent water	4.1	118	-	1,867	502	1,850	76
Clarifier effluent water	4.7	113	12	1,833	517	1,833	83
Quench water	9.0	118	254	730	282	785	44
No. 5							
Process water	7.1	-	204	88	65	205	81
Scrubber effluent water	3.8	-	-	2,572	596	2,510	96
Clarifier effluent water	4.6	-	6	2,345	530	2,293	70
Quench water	10.1	-	460	781	225	825	20

TABLE 12

SUMMARY OF STACK GAS COMPOSITION

Test run	CO_2 (%)	O_2 (%)	CO (%)	N_2 (%)	Special gases: NO_x (ppm)	Special gases: HCl (ppm)
1	4.3	16.3	0.0	79.4	32	17
2	3.6	17.0	0.0	79.4	32	27
3	4.2	16.5	0.0	79.3	-	-
4	4.2	16.3	0.0	79.5	42	19
Average	4.1	16.5	0.0	79.4	35	21

analyses for nitrogen oxides and hydrochloric acid are also presented in Table 12. The particulate emissions (Table 13) include the weight of material remaining after the evaporation of the impinger water. The charging rate for the stack tests was the average charging rate for the respective 8-hr shift (see Appendix D).

Plant Efficiency

An indication of the plant's performance is obtained by calculating the percent volatile reduction, the percent heat released and the percent volume reduction (Table 14). These calculations are presented in Appendix C.

The wastewater flow was not measured and the volume, volatile, and heat contents of the solid material carried by these waters were not determined during the study period. Because these values were not used in the plant efficiency calculations, the efficiencies shown are slighty higher than they would have been if these values had been included.

Bacteriological Analyses

Samples of the solid waste, residue, fly ash, process water, quench water effluent and clarifier water effluent were analyzed for total bacteria, heat resistant spores, coliforms, and salmonella (Table 15).

Cost Analyses

The annual cost (Table 16) of the incinerator was based on a 1-year time period from January 1969 to January 1970.

TABLE 13

SUMMARY OF STACK TESTS

Test run	Time (min)	Average CO_2 content in stack gases (%)	Stack gas temperature (F)	Excess air (%)	Stack gas flow		Particulate emissions			
					scfm	acfm	gr/scf at 12% CO_2	lb/1,000 lb at 50% E.A.	lb/hr	lb/ton waste
1	75	4.3	492	347	145,800	279,700	0.33	0.66	143	7.14
2	72	3.6	457	429	145,700	267,700	0.41	0.81	150	7.48
3	72	4.2	480	371	151,600	285,000	0.35	0.72	157	7.83
4	72	4.2	482	348	140,800	266,500	0.34	0.66	142	7.08
Average	-	4.1	478	374	146,000	274,700	0.36	0.71	148	7.38

TABLE 14

PLANT EFFICIENCY*

Type of efficiency	Percent efficiency
Reduction in volatiles	96.3
Reduction in heat content	96.1
Volume reduction	94.8

*See Appendix C.

TABLE 15

RESULTS OF BACTERIOLOGICAL STUDY

Source	Date	Total viable cell count	Heat resistant spore count	Coliform count: Total	Coliform count: Fecal	Salmonella
Solid waste	1-26-70	1.7×10^6/g	1.0×10^2/g	7.0×10^5/g	3.1×10^5/g	NI
	1-27-70	4.0×10^6/g	1.6×10^4/g	2.4×10^6/g	3.5×10^5/g	NI
	1-28-70	3.0×10^7/g	1.0×10^3/g	1.7×10^7/g	1.7×10^7/g	NI
Residue	1-26-70	5.0×10^4/g	3.0×10^2/g	ND	ND	NI
	1-27-70	1.3×10^3/g	1.0×10^2/g	ND	ND	NI
	1-28-70	2.0×10^2/g	1.0×10^2/g	ND	ND	NI
Fly ash	1-26-70	3.0×10^5/g	1.0×10^4/g	1.6×10^5/g	1.6×10^5/g	NI
	1-27-70	4.0×10^5/g	4.0×10^2/g	3.3×10^4/g	3.3×10^4/g	NI
	1-28-70	1.5×10^6/g	1.5×10^3/g	3.1×10^4/g	3.1×10^4/g	NI
Process water	1-26-70	5.0×10^8/100 ml	5.0×10^4/100 ml	4.9×10^8/100 ml	4.9×10^8/100 ml	NI
	1-27-70	9.0×10^8/100 ml	3.0×10^4/100 ml	4.6×10^8/100 ml	7.0×10^7/100 ml	NI
Quench water effluent	1-26-70	1.0×10^5/100 ml	1.0×10^5/100 ml	ND	ND	NI
	1-27-70	4.0×10^4/100 ml	1.0×10^4/100 ml	ND	ND	NI
	1-28-70	1.4×10^4/100 ml	1.0×10^4/100 ml	200/100 ml	200/100 ml	NI
Clarifier water effluent	1-26-70	1.3×10^7/100 ml	1.6×10^4/100 ml	1.6×10^7/100 ml	1.6×10^7/100 ml	NI
	1-27-70	3.0×10^5/100 ml	1.2×10^5/100 ml	ND	ND	NI
	1-28-70	7.0×10^4/100 ml	1.3×10^4/100 ml	ND	ND	NI

NI - Not isolated

ND - No counts detected in testing sample (see reference 10)

TABLE 16

ANNUAL COST ANALYSES

JANUARY 1969 TO JANUARY 1970

Item	Cost	Cost per ton*	Percent of annual cost
Operating costs			
Direct labor and fringe benefits	$153,009	$1.55	27.0
Utilities (electric, gas, sewage, etc.)	17,000	0.17	3.0
Parts and supplies	8,000	0.08	1.4
Vehicle operating expenses	300	0.00	0.0
External repair charges	119,000	1.20	21.0
Disposal charges	0	0.00	0.0
Overhead	69,003	0.70	12.2
Subtotal	366,312	3.70	64.6
Financing and ownership			
Plant depreciation	129,100	1.31	22.8
Interest (at 3.125%)	71,343	0.72	16.6
Subtotal	200,443	2.03	35.4
Total annual cost	566,755	5.73	100.0

*Based on actual input of 98,928 tons, or 380 tons per day

The financing and ownership costs (Table 17) were based on a capital cost in 1962 of $2,283,000. The building depreciation was calculated on a straight-line basis by dividing the capital cost by the building's life of 30 years. The same method was used to calculate the general equipment and vehicle depreciation with the general equipment having a 15-year life and the vehicles having a 5-year life. Site improvement, consultant fees, and miscellaneous were depreciated over the building life.

The annual operating cost (Table 18) was allocated to the following cost centers: receiving, which includes items associated with the storage pit, crane, and scale operations; volume reduction, which includes items associated with the furnace operation; and effluent treatment, which includes items associated with residue disposal, air pollution control, and wastewater treatment operations. Allocation of the operating costs into cost centers was achieved through the use of physical factors, such as the number of people involved, power requirements, and the time and material used in each cost center.

The cost of repairs and maintenance and its allocation to cost centers was calculated (Table 19).

The labor costs in the projected annual cost at design capacity (Table 20) remain the same because the plant is fully staffed. The financing and ownership costs also remain the same because the expected plant life is 30 years. The utilities, parts and supplies, vehicle operating expenses, external repair charges,

TABLE 17

CAPITAL COST

Item	Cost	Cost per ton of design capacity*
Building	$ 800,000	$1,600
Equipment		
General	1,200,000	2,400
Automotive	78,000	156
Site improvement	50,000	100
Consultant fees	100,000	200
Miscellaneous	55,000	110
Land	0	0
Total costs	2,283,000	4,566

*Design capacity is 500 tons per day.

TABLE 18

OPERATING COST BY COST CENTERS

Cost center	Operating cost	Percent of operating costs	Percent of annual cost
Receiving:			
Direct labor	$ 51,004	13.9	9.0
Utilities	10,000	2.7	1.7
Vehicle operating expense	0	0.0	0.0
Repairs and maintenance	18,187	5.0	3.2
Overhead	23,000	6.3	4.1
Subtotal	102,191	27.9	18.0
Volume reduction:			
Direct labor	25,502	7.0	4.5
Utilities	4,000	1.1	0.7
Repairs and maintenance	118,878	32.4	21.0
Overhead	11,500	3.1	2.0
Subtotal	159,880	43.6	28.2
Effluent treatment			
Direct labor	57,377	15.7	10.1
Utilities	3,000	0.8	0.5
Vehicle operating expense	300	0.1	0.1
Disposal charge	0	0.0	0.0
Repairs and maintenance	17,686	4.8	3.1
Overhead	25,878	7.1	4.6
Subtotal	104,241	28.5	18.4
Total operating cost	366,312	100.0	64.6

TABLE 19

REPAIRS AND MAINTENANCE COST ANALYSES

Cost of repairs and maintenance		Cost allocation to direct cost centers		
Item	Cost	Cost center	Allocation	Percent of total
Labor	\$ 19,126	Receiving	\$ 18,187	11.8
Parts	8,000	Volume reduction	118,878	76.8
External charges	119,000	Effluent treatment	17,686	11.4
Overhead	8,625	Total	154,751	100.0
Total	154,751			

TABLE 20

PROJECTED ANNUAL COST AT DESIGN CAPACITY*

Item	Projected annual cost	Cost per ton	Percent of total projected annual cost
Operating costs			
Direct labor and fringe benefits	$153,009	$1.18	25.1
Utilities (electric, gas, sewage, etc.)	22,339	0.17	3.6
Parts and supplies	10,512	0.08	1.7
Vehicle operating expenses	396	0.00	0.0
External repair charges	156,376	1.20	25.5
Disposal charges	0	0.00	0.0
Overhead	69,003	0.53	11.3
Subtotal	411,635	3.16	67.2
Financing and ownership			
Plant depreciation	129,100	0.99	21.1
Interest	71.343	0.55	11.7
Subtotal	200,443	1.54	32.8
Total annual cost	612,078	4.70	100.0

*Based on design capacity of 500 tons per day, or an annual input of 130,100 tons and disposal charges are assumed to vary linearly with the level of input.

Industrial Hygiene

An industrial hygiene survey of the incinerator was made during the study period. The potential hazards investigated were: excessive dust, heat, noise and smoke exposure, and inadequate lighting. The results of this survey are shown in Table 21. This survey found that during the study period the dust concentration and noise levels were below maximum permissible levels and presented no health hazard. The potential heat stress presented no health hazard at the time of the study period, but when the outdoor temperature does exceed 75 F, the heat stress may be excessive in the middle of the furnace floor between the furnaces.

In two plant areas, the furnace feed platform (at the top of the drying grate) and the quench tank area, the lighting levels were below recommended levels.

Excessive smoke is generated in a 5-in. gap between the charging hopper and the drying grate. This smoke is probably the most serious hazard in the plant.

TABLE 21

INDUSTRIAL HYGIENE STUDY

Location	Sound level Network A (db)	Sound level Network B (db)	Sound level Network C (db)	Heat stress Dry (F)	Heat stress Wet (F)	Heat stress Globe temperature (F)	Dust (mg/m^3)	Light (fc)
Hopper platform (3rd floor)								
West side	84*	88	92				0.66	30
Between hoppers	84*	88	92				1.20	20
East side	84*	88	92					15
Feed platform (2nd floor)								
East side	72	78	86					5
West side	72	77	81					5
North side	69	75	82					<5
Outside lunchroom	71	77	83					<5
Middle	72	76	81					<5
Furnace floor (1st floor)								
East wall	76	81	86					150
Control panel	79	81	86					40
South wall	76	79	83					10
Middle	75	78	83	54	72	81		10
North wall	72	78	84					10
West wall	78	82	85					40
Outside office	78	83	86					15

*Peaks: 92 db A at 5-sec intervals

TABLE 21 (Continued)

INDUSTRIAL HYGIENE STUDY

Location	Sound level Network A (db)	B (db)	C (db)	Heat stress Dry (F)	Wet (F)	Globe temperature (F)	Dust (mg/m^3)	Light (fc)
Quench floor								
At maintenance shop	85	91	94					5
Between blowers	89	95	101					5
Inside doors	89	93	99					5
Catwalk, east end	85	91	94					10
Catwalk, middle	88	91	94					5
Catwalk, west end	86	90	94					5
South wall, east end	85	92	94	49	60.5	-		20
South wall, middle	87	90	93					10
South wall, west end	85	89	92					5
Conveyor, east end	79	84	87					120
Conveyor, middle	81	85	88					100
Conveyor, west end	82	86	90					25

Outside temperatures: dry, 42 F; wet, 39.5 F; and relative humidity, 80%

Standards: Sound--T. L. V. for db A: 90 for 8 hr/day, 92 for 6 hr/day (see reference 11)

Dust --T. L. V. is mg/m^3 (see reference 12)

Light--Minimum: 5fc--storage area, 10fc--general area, and 20fc--materials handling area (see reference 13)

Heat --See reference 14

T. L. V. = threshold limit value

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Sample analyses were performed by the Division of Research and Development, Bureau of Solid Waste Management.

The industrial hygiene study was performed by John M. Blankenhorn, Occupational Safety and Health Training, Environmental Control Administration.

APPENDICES

APPENDIX A

Example Calculations for Results of Solid Waste Proximate Analysis

Using the data from the laboratory analyses of solid waste sample No. 1 (Table A-1) these example calculations show the methods used to calculate the moisture content, ash and volatile content, and the heat content of the total sample. The volatile and ash fractions and the heat content of the laboratory samples are on a dry basis. For these calculations, the noncombustibles were assumed to contain no heat and no volatile material. The field separation determined a combustible content of 73.5 percent and a noncombustible content of 26.5 percent (Table 3) on a wet basis.

TABLE A-1

PROXIMATE ANALYSES OF THE SOLID WASTE SAMPLES

Sample number	Noncombustibles	Combustibles			
	Moisture (%)	Moisture (%)	Volatiles (%)	Ash (%)	Heat (Btu/lb)
1	10.0	30.8	91.7	8.3	8,220
2	5.9	56.5	87.6	12.4	7,905
5	7.4	41.5	86.3	13.7	7,625
6	6.3	32.8	89.1	11.9	8,055
8	6.9	33.9	87.1	12.9	8,210

<u>Moisture Content.</u> The percent moisture in the total sample was calculated by the following method:

$$\text{Percent moisture in total sample} = \left[\left(\frac{\text{lb combustibles}}{\text{lb waste}}\right)\left(\frac{\text{lb moisture}}{\text{lb combustibles}}\right) + \left(\frac{\text{lb noncombustibles}}{\text{lb waste}}\right)\left(\frac{\text{lb moisture}}{\text{lb noncombustibles}}\right)\right] 100.0$$

$$\text{Percent moisture in total sample (No. 1)} = (0.735)(0.308) + (0.265)(0.100)\ 100.0$$

$$= 22.6 + 2.7 = 25.3$$

<u>Volatile and Ash Contents.</u> Because the volatile and ash fractions are calculated on a dry basis, the percent combustibles and noncombustibles must be converted to a dry basis by means of the following equation:

$$\text{Percent dry component} = \left(\frac{\text{lb wet component - lb moisture in component}}{\text{dry sample weight}}\right) 100.0$$

$$\text{Percent dry combustibles in total sample (No. 1)} = \left(\frac{179.1 - 55.2}{181.8}\right) 100.0 = 68.2$$

These calculations are summarized in Table A-2.

TABLE A-2

CONVERSION OF THE COMBUSTIBLE AND NONCOMBUSTIBLE DATA TO A DRY BASIS

Component	Wet weight (lb)	Moisture (%)	Moisture (lb)	Dry weight (lb)	Percent by dry weight
Combustibles	179.1	30.8	55.2	123.9	68.2
Noncombustibles	64.3	10.0	6.4	57.9	31.8
Total sample	243.4	25.3	61.6	181.8	100.0

The percent of volatiles and ash was calculated as follows:

$$\text{Percent volatiles in total sample} = \left(\frac{\text{lb volatiles}}{\text{lb dry combustibles}}\right)\left(\frac{\text{lb dry combustibles}}{\text{lb dry waste}}\right) 100.0$$

$$\text{Percent volatiles in total sample (No. 1)} = (0.917)(0.682)(100.0) = 62.5$$

$$\text{Percent ash in total sample} = 100.0 - \text{percent volatiles}$$

$$\text{Percent ash in total sample (No. 1)} = 100.0 - 62.5 = 37.5$$

Heat Content. The laboratory reports the heat content on a dry basis for the combustibles only, thus the moisture content and the noncombustibles in the total sample must be accounted for when calculating the heat content of the total sample on an "as received" basis.

$$\text{Heat content of total sample} = \left(\frac{\text{Btu}}{\text{lb dry combustibles}}\right)\left[1 - \left(\frac{\text{\% moisture in combustibles} + \text{\% wet noncombustibles}}{100.0}\right)\right]$$

$$\text{Heat content of total sample (No. 1)} = (8{,}220)\left[1.0 - \left(\frac{22.6 + 26.5}{100.0}\right)\right]$$

$$= 4{,}184 \text{ Btu per lb waste}$$

APPENDIX B

Example Calculations for Results of Residue Proximate Analysis

Using the data from the laboratory analyses of residue sample No. 1 (Table B-1) these example calculations show the methods used to calculate the moisture content, ash and volatiles content, and heat content of the total sample. The volatile and ash fractions and the heat content of the laboratory samples are on a dry basis.

The amount of metal, glass, fines, and unburned combustibles found during the field separation was 9.6, 20.9, 56.9, and 12.6 percent respectively on a wet-weight basis (Table 6). For these calculations, the metal and glass were assumed to contain no heat and no volatile material.

Moisture Content. The percent moisture in the total sample was calculated by the following method:

$$\begin{aligned}\text{Percent moisture in total sample} &= \left(\frac{\text{lb metal}}{\text{lb residue}}\right)\left(\frac{\text{lb moisture}}{\text{lb metal}}\right) + \left(\frac{\text{lb glass}}{\text{lb residue}}\right)\left(\frac{\text{lb moisture}}{\text{lb glass}}\right)\\ &+ \left(\frac{\text{lb fines}}{\text{lb residue}}\right)\left(\frac{\text{lb moisture}}{\text{lb fines}}\right)\\ &+ \left(\frac{\text{lb unburned combustibles}}{\text{lb residue}}\right)\left(\frac{\text{lb moisture}}{\text{lb unburned combustibles}}\right) 100.0\end{aligned}$$

$$\begin{aligned}\text{Percent moisture in total sample (No. 1)} &= \left[(0.096)(0.176) + (0.209)(0.096)\right.\\ &\left.+ (0.569)(0.343) + (0.126)(0.600)\right] 100.0\\ &= 30.8\end{aligned}$$

TABLE B-1

PROXIMATE ANALYSES OF THE RESIDUE

Sample no.	Metal	Glass	Unburned combustibles				Fines			
	Moisture (%)	Moisture (%)	Moisture (%)	Volatiles (%)	Ash (%)	Heat (Btu per lb)	Moisture (%)	Volatiles (%)	Ash (%)	Heat (Btu per lb)
1	17.6	9.6	60.0	52.0	48.0	4,590	34.3	11.6	88.4	1,130
2	8.1		55.2	56.9	43.1	6,535	28.9	5.8	94.2	475
3	16.0	6.3	63.9	63.9	36.1	5,525	43.2	6.8	93.2	590
4	11.6	7.4	70.0	49.1	50.9	5,585	42.6	5.8	94.2	470
5	13.6	8.5	76.0	62.1	37.9	5,940	44.2	6.4	93.6	625

Volatile and Ash Contents. Because the remaining calculations are on a dry basis, the separation data from Table 6 must be converted to a dry basis by the following method:

$$\text{Percent dry component} = \left(\frac{\text{lb wet component - lb moisture in wet component}}{\text{total dry sample weight}}\right) 100.0$$

$$\text{Percent dry unburned combustibles in total sample (No. 1)} = \left(\frac{5.3 - 3.2}{28.2}\right) 100.0$$

$$= 7.2$$

TABLE B-2

CONVERSION OF THE RESIDUE DATA TO A DRY BASIS

Component	Wet weight (lb)	Moisture (%)	Moisture (lb)	Dry weight (lb)	Percent by dry weight
Unburned combustibles	5.3	60.0	3.2	2.1	7.2
Fines	23.8	34.3	8.2	15.6	53.8
Glass	8.8	9.6	0.8	8.0	27.6
Metal	4.0	17.6	0.7	3.3	11.4
Total sample	4.9	30.8	12.9	29.0	100.0

The percent of volatiles and ash was calculated as follows:

$$\text{Percent volatiles in total sample} = \left[\left(\frac{\text{lb volatiles}}{\text{lb dry fines}}\right)\left(\frac{\text{lb dry basis}}{\text{lb dry residue}}\right) + \left(\frac{\text{lb volatiles}}{\text{lb dry unburned combustibles}}\right)\left(\frac{\text{lb dry unburned combustibles}}{\text{lb dry residue}}\right)\right] 100.0$$

$$\text{Percent volatiles in total sample (No. 1)} = \left[(0.116)(0.538) + (0.52)(0.072)\right]100.0 = 10.0$$

$$\text{Percent ash in total sample} = 100.0 - \text{percent volatiles}$$

$$\text{Percent ash in total sample (No. 1)} = 100.0 - 10.0 = 90.0$$

<u>Heat Content.</u> The laboratory reports the heat content on a dry basis for the fines and unburned combustibles, and therefore the heat content of the total sample on a dry basis is calculated as follows:

$$\text{Heat content of total sample on a dry basis} = \left(\frac{\text{Btu}}{\text{lb dry fines}}\right)\left(\frac{\text{lb dry fines}}{\text{lb dry residue}}\right) + \left(\frac{\text{Btu}}{\text{lb dry unburned combustibles}}\right)\left(\frac{\text{lb dry unburned combustibles}}{\text{lb dry residue}}\right)$$

$$\text{Heat content of total sample (No. 1) on a dry basis} = (1{,}130)(0.538) + (4{,}590)(0.072)$$

$$= 938$$

APPENDIX C

Plant Efficiency Calculations

These calculations show the methods used to calculate the percent reduction of volatile material, the percent heat released, and the percent volume reduction. The following data were used:

Solid Waste:	2,023	tons (wet)
	31.6	percent moisture
	1,384	tons (dry)
	3,659	Btu per lb (wet)
	59.1	percent volatiles (dry)
	190	lb per cu yd (wet)
Residue:	785	tons (wet)
	27.3	percent moisture
	571	tons (dry)
	488	Btu per lb (dry)
	5.2	percent volatiles (dry)
	1,455	lb per cu yd (wet)
Fly Ash.		
Furnace clean-out:	3	tons (wet
	48.2	percent moisture
	1.6	tons (dry)
	188	Btu per lb (dry)
	2.8	percent volatiles (dry)
	1,295	lb per cu yd (dry)
Clarifier:	3	tons (wet)
	34.9	percent moisture
	2	tons (dry)
	367	Btu per lb (dry)
	3.6	percent volatiles (dry)
	1,460	lb per cu yd (dry)
Particulate:	148	lb per hr (dry)
	232	hr
	367	Btu per lb (dry)*
	3.6	percent volatiles (dry)*
	1,460	lb per cu yd (dry)*

*Assumed the same as that of the fly ash removed from the clarifier

$$\text{Percent volatile reduction} = \left[1 - \left(\frac{\text{volatile content of the residue} + \text{volatile content of the fly ash} + \text{volatile content of the wastewater solids*}}{\text{volatile content of the solid waste}}\right)\right]100.0$$

$$\text{Percent volatile reduction} = \left\{1 - \left[\frac{(571)(2{,}000)(0.052) + (1.6)(2{,}000)(0.028) + (2)(2{,}000)(0.036) + (148)(232)(0.036)}{(1{,}384)(2{,}000)(0.591)}\right]\right\}100.0$$

$$\text{Percent volatile reduction} = 96.3$$

$$\text{Percent heat release} = \left[1 - \left(\frac{\text{heat content of the residue} + \text{heat content of the fly ash} + \text{heat content of the wastewater solids*}}{\text{heat content of the solid waste}}\right)\right]100.0$$

$$\text{Percent heat release} = \left\{1 - \left[\frac{(571)(2{,}000)(488) + (1.6)\ (2{,}000)(188) + (2)(2{,}000)(367) + (148)(232)(367)}{(2{,}023)(2{,}000)(3{,}659)}\right]\right\}100.0$$

$$\text{Percent heat release} = \left[1 - \left(\frac{557{,}296{,}000 + 601{,}600 + 1{,}468{,}000 + 12{,}601{,}312}{14{,}804{,}314{,}000}\right)\right]100.0$$

$$\text{Percent heat release} = (1 - 0.0386)100.0$$

$$\text{Percent heat release} = 96.1$$

---

*Not measured

$$\text{Percent volume reduction} = \left[1 - \left(\frac{\text{volume of residue} + \text{volume of fly ash} + \text{volume of wastewater solids*}}{\text{volume of solid waste}}\right)\right]100.0$$

$$\text{Percent volume reduction} = \left\{1 - \left[\frac{\frac{(785)(2{,}000)}{1{,}455} + \frac{3{,}200}{1{,}295} + \frac{4{,}000}{1{,}460} + \frac{(148)(232)}{1{,}460}}{\frac{(2{,}023)(2{,}000)}{190}}\right]\right\}100.0$$

$$\text{Percent volume reduction} = \left[1 - \left(\frac{1{,}079 + 2 + 3 + 24}{21{,}295}\right)\right]100.0$$

$$\text{Percent volume reduction} = (1 - 0.052)100.0$$

$$\text{Percent volume reduction} = 94.8$$

*Not measured

APPENDIX D

Daily Reports

DAILY REPORT

INCINERATOR PLANT NO. 3

DATE Jan. 26. 70 Monday Start up.

	1st Shift 12m to 8 AM	2nd Shift 8AM to 4 PM	3rd Shift 4 PM to 12m	Totals for Day
No. Trucks Rec.		93	37	130
No. Tons Rec.		317	135	452
Furn. Hrs.		14	16	30
No. Buckets		163	185	348
Refuse in Bin Start of Shift	Ft. 154 T.	12 1/2 Ft. 12T 154 T.	27 Ft. 12T 324 T.	
Refuse in Bin End of Shift	Ft. 154 T.	27 Ft. 12T 324 T.	24 Ft. 12T 288 T.	
Tons Burned		147	171	318
Tons per F. Hr.		10.5	10.6	10.6
Av. Temp.		1171	1468	1329
Stoker Revs.		123	143	266
		#1-50-50 #2-50-50	#1-50-50 #2-50-50	
No. Ash Tr. Dumped		8	12	20
No. Tons Dumped		43.05	65.58	108.63
Weather		Clear	Clear	
Wind Blowing from		NW	NW	

Remarks: Each load is actual weight Wet. Residue. One foot Material = 12 Tons in Pit.

P. L. Cummings
Superintendant

DAILY REPORT

INCINERATOR PLANT NO. 3

DATE Jan. 27-70 Tuesday

	1st Shift 12m to 8 AM	2nd Shift 8AM to 4 PM	3rd Shift 4 PM to 12m	Totals for Day
No. Trucks Rec.		99	25	124
No. Tons Rec.		328	82	410
Furn. Hrs.	16	16	16	48
No. Buckets	182	177	169	525
Refuse in Bin Start of Shift	24 Ft. 288 T. (12 T)	10 Ft. 120 T. (12 T)	24 Ft. 288 T. (12 T)	
Refuse in Bin End of Shift	10 Ft. 120 T. (12 T)	24 Ft. 288 T. (12 T)	18 Ft. 216 T. (12 T)	
Tons Burned	168	160	154	482
Tons per F. Hr.	10.5	10	9.6	10
Av. Temp.	1568	1415	1037	1340
Stoker Revs.	147	138	98	383
	#1-50-50 #2-50-50	#1-45-45 #2-45-45	#1-35-35 #2-35-35	
No. Ash Tr. Dumped	14	13	9	36
No. Tons Dumped	83.81	65.755	43	192.56
Weather	Clear	Clear	Snow	
Wind Blowing from	NW	NW	South	

Remarks: Each Load is actual weight Wet Residue Had To Slow down Speed on 3Rd Shift To save Material for a light load for Wed.
Material very light this Time of year

Pat Cummings
Superintendant

DAILY REPORT

INCINERATOR PLANT NO.

DATE Jan. 28-70 Wed.

	1st Shift 12^m to 8 AM	2nd Shift 8AM to 4 PM	3rd Shift 4 PM to 12^m	Totals for Day
No. Trucks Rec.		62	5	67
No. Tons Rec.		196	9	205
Furn. Hrs.	16	16	16	48
No. Buckets	124	178	100	402
Refuse in Bin Start of Shift	18 Ft. 216 T.	10 Ft. 120 T.	13 Ft. 156 T.	
Refuse in Bin End of Shift	10 Ft. 120 T.	13 Ft. 156 T.	7 Ft. 84 T.	
Tons Burned	96	160	81	337
Tons per F. Hr.	6	10	5	7
Av. Temp.	725	1340	775	946
Stoker Revs.	49	149	68	266
	#1- Idle #2 Idle	#1-45-45 #2-45-45	#1- Idle #2- Idle	
No. Ash Tr. Dumped	4	12	7	23
No. Tons Dumped	21.785	59.315	34.12	115.21
Weather	Cloudy	Clear	Cloudy	
Wind Blowing from	NW	S	SE	

Remarks: Each load is actual weight Wet Residue
Had to slow down speed on first and third Shift
Was very light load Material

P. L. Cummings
Superintendant

DAILY REPORT

INCINERATOR PLANT NO. 3

DATE Jan. 29-70 Thurs.

	1st Shift 12^{m} to 8 AM	2nd Shift 8AM to 4 PM	3rd Shift 4 PM to 12^{m}	Totals for Day
No. Trucks Rec.		116	5	121
No. Tons Rec.		376	19	395
Furn. Hrs.	16	16	16	48
No. Buckets	73	181	130	384
Refuse in Bin Start of Shift	7 Ft. 84 T.	1 Ft. 12 T.	19 Ft. 228 T.	
Refuse in Bin End of Shift	1 Ft. 12 T.	19 Ft. 228 T.	10 Ft. 120 T.	
Tons Burned	72	160	127	359
Tons per F. Hr.	4.5	10	7.9	7.4
Av. Temp.	615	1290	1334	1079
Stoker Revs.	44	132	110	286
	#1 - Idle #2 - Idle	#1 - 50 - 50 #2 - 50 - 50	#1 - 25 - 30 #2 - 25 - 30	
No. Ash Tr. Dumped	3	12	9	24
No. Tons Dumped	17.71	59.69	50.24	127.64
Weather	Cloudy	Clear	Rain	
Wind Blowing from	SW	SW	SW	

Remarks: Each Load is actual weight Wet Residue. Idle down on First Shift and Slow down on Third Shift.

P. J. Cummings
Superintendant.

DAILY REPORT

INCINERATOR PLANT NO. 3

DATE Jan. 30 - 70 Friday.

	1st Shift 12m to 8 AM	2nd Shift 8AM to 4 PM	3rd Shift 4 PM to 12m	Totals for Day
No. Trucks Rec.		115	11	126
No. Tons Rec.		376	31	407
Furn. Hrs.	16	16	16	48
No. Buckets	126	183	185	494
Refuse in Bin Start of Shift	10 Ft. 120 T.	1 Ft. 12 T.	19 Ft. 228 T.	
Refuse in Bin End of Shift	1 Ft. 12 T.	19 Ft. 228 T.	8 Ft. 96 T.	
Tons Burned	108	160	163	431
Tons per F. Hr.	6.7	10	10.1	8.9
Av. Temp.	1100	1287	1638	1341
Stoker Revs.	90	132	146	368
	#1-15--15 #2-15-15	#1-50-50 #2-50-50	#1-50-50 #2-50-50	
No. Ash Tr. Dumped	7	11	17	35
No. Tons Dumped	38.66	53.865	83.42	175.94
Weather	Clear	Clear	Clear	
Wind Blowing from	NW	NW	NW	

Remarks: Idle down on First Shift
Material Low.
2nd & 3rd Shift Normal

R. L. Cummings
Superintendant

DAILY REPORT

INCINERATOR PLANT NO. 3

DATE Jan 31-70 12m to 8AM

	1st Shift 12m to 8 AM	2nd Shift 8AM to 4 PM	3rd Shift 4 PM to 12m	Totals for Day
No. Trucks Rec.	∞			
No. Tons Rec.	∞			
Furn. Hrs.	10			
No. Buckets	123			
Refuse in Bin Start of Shift	8 Ft. 96 T.	Ft. T.	Ft. T.	
Refuse in Bin End of Shift	0 Ft. 0 T.	Ft. T.	Ft. T.	
Tons Burned	96			
Tons per F. Hr.	9.6			
Av. Temp.	1696			
Stoker Revs.	82			
	#1-50-50 #2-50-50			
No. Ash Tr. Dumped	11			
No. Tons Dumped	63.53			
Weather	Clear			
Wind Blowing from	N.W.			

Remarks: Shut down first shift. End of Week.

R. L. Cummings
Superintendant